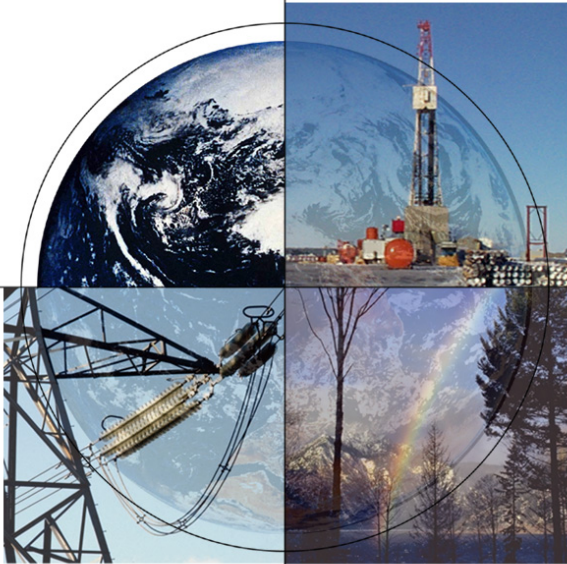


U. S. Department of Energy National Energy Technology Laboratory



“Future of Fossil Energy in Alaska”

Enhanced Oil Recovery

April 11, 2002

Charles Thomas

Dr. Dennis E. Witmer, University of Alaska Fairbanks (ffdew@uaf.edu)

Mr. Brent J. Sheets, National Energy Technology Laboratory (brent.sheets@netl.doe.gov)

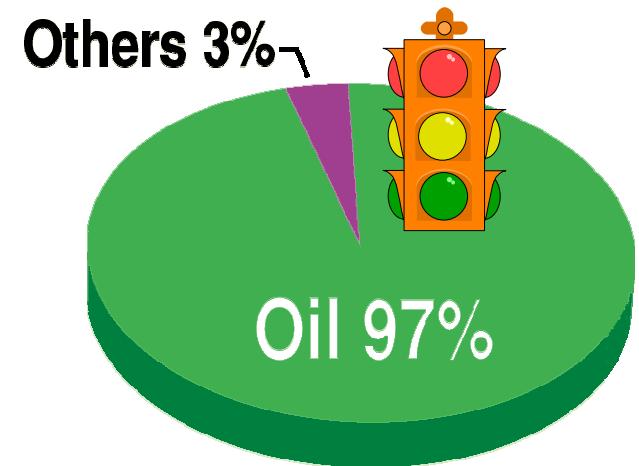
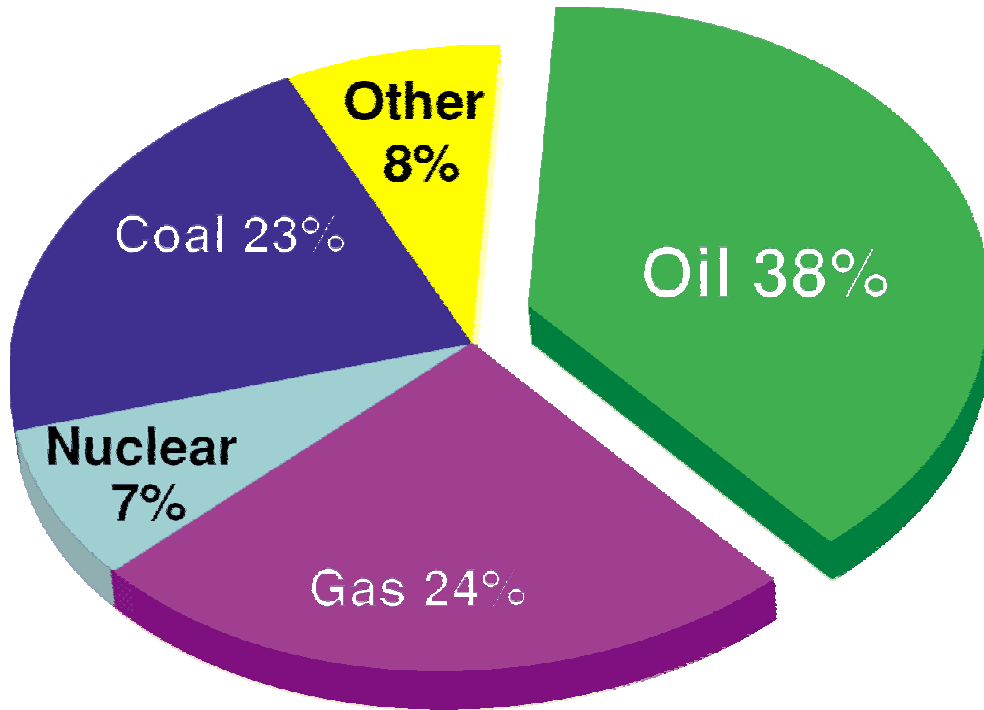
Dr. Charles P. Thomas, National Energy Technology Laboratory (SAIC) (Charles.Thomas@saic.com)



Outline

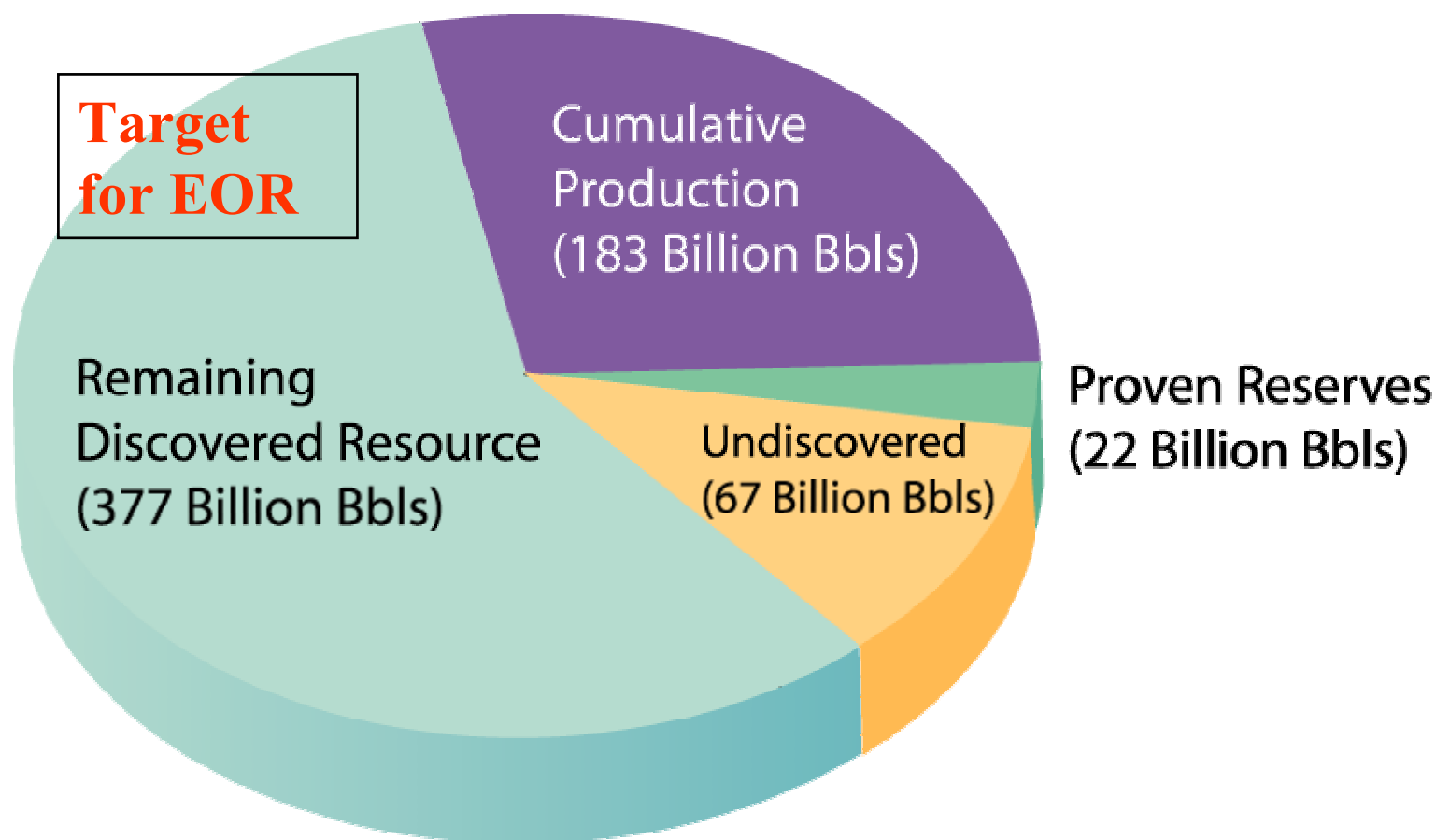
- Importance of oil to U.S. and to Alaska
- Historical perspective on EOR
- Lessons learned
- ANS Example
- Conclusions

U.S. Energy Consumption



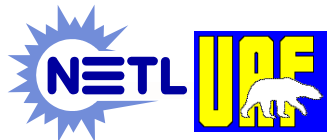
Transportation

Two-Thirds of U.S. Oil Resource Remains after Conventional Production



Alaska Reserves and Production

- **36% of total U.S. oil reserves.**
- 8.0 billion barrels of oil
- **17% of total U.S. gas reserves**
- 35 trillion cubic feet of gas
- **20% of total U.S. oil production**
- 1.04 million barrels of oil per day



Sources: Alaska data are from Department of Natural Resources, Division of Oil and Gas, 2001 Annual Report
U.S. data are from U.S. Crude Oil, Natural Gas, and NGL Reserves, 2000 Annual Report, U.S.D.O.E.-E.I.A.

The State Revenue Pie

Petroleum Revenue Sources, (FY 2001)

Total Royalties, Bonuses, Rents & Settlements:

\$1,145.9 Million

General Fund Royalties, Bonuses & Rents^{1,2}:
\$798.8 Million

Royalties to Permanent Fund &
School Fund⁴:
\$337.1 Million

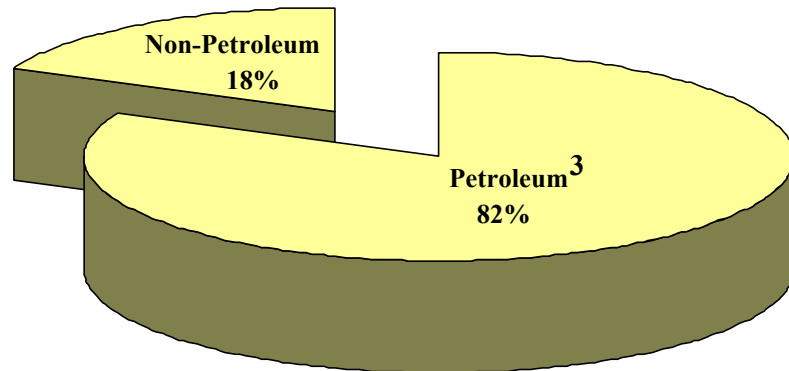
Settlements to CBRF⁴:
\$10.0 Million
(Includes Royalties & Taxes)

Taxes:

\$1,125.4 Million²

(Oil & Gas Property Tax + Tax Settlements +
Income Tax + Severance Tax)

FY 2001 Unrestricted Revenue

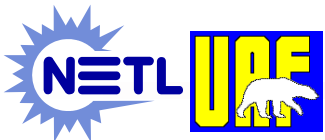


¹ Includes Federally shared rentals

² Source: pg. 23, DOR Fall 2001 Revenue Sources Book

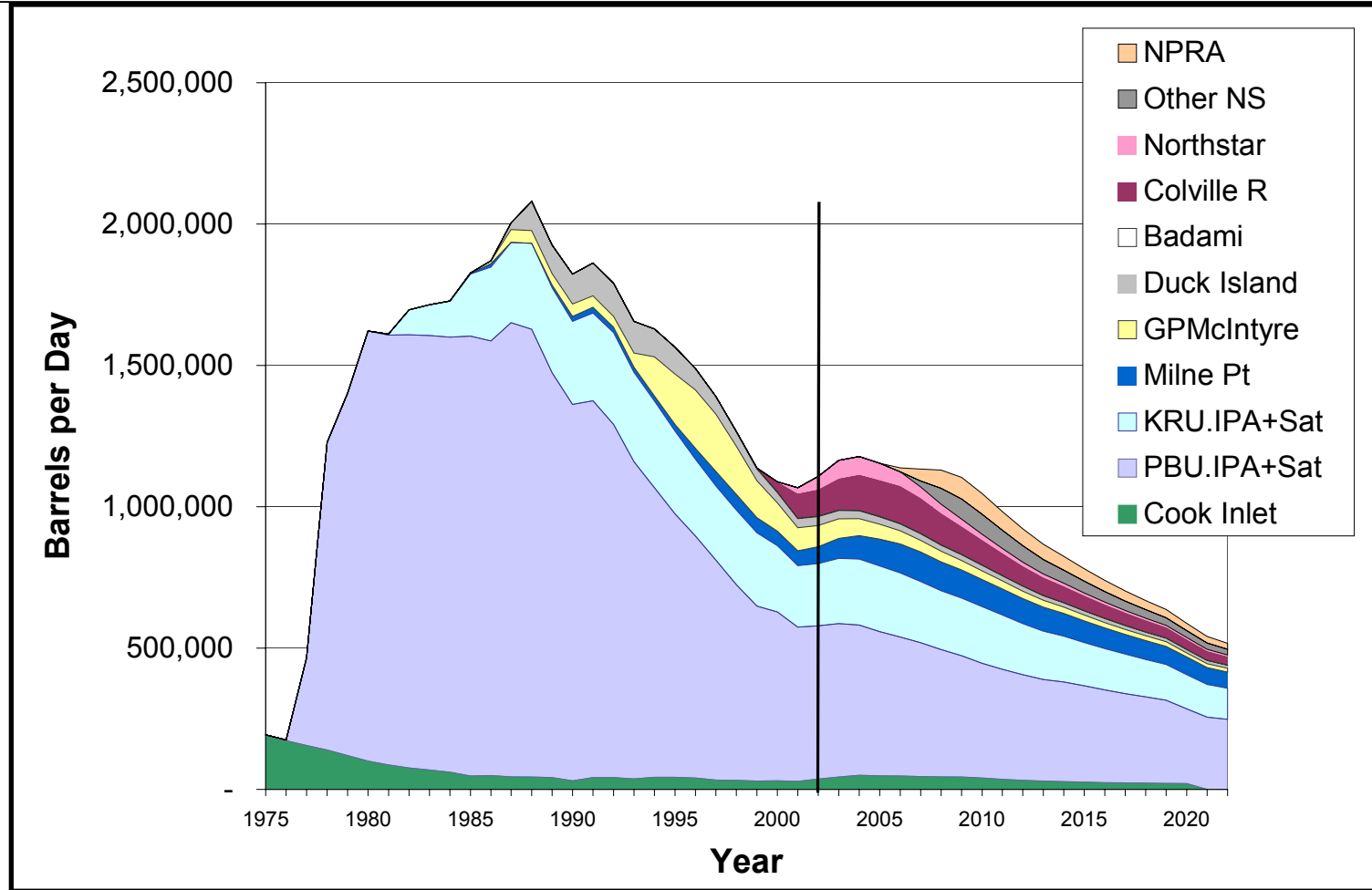
³ Source: pg. 22, DOR Fall 2001 Revenue Sources Book

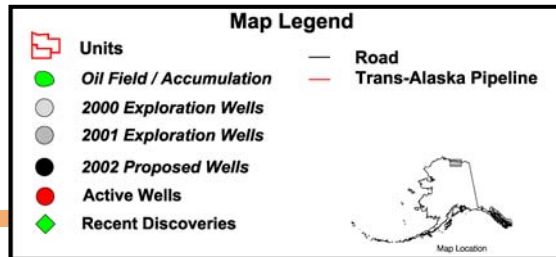
⁴ Source: pg. 19, DOR Fall 2001 Revenue Sources Book



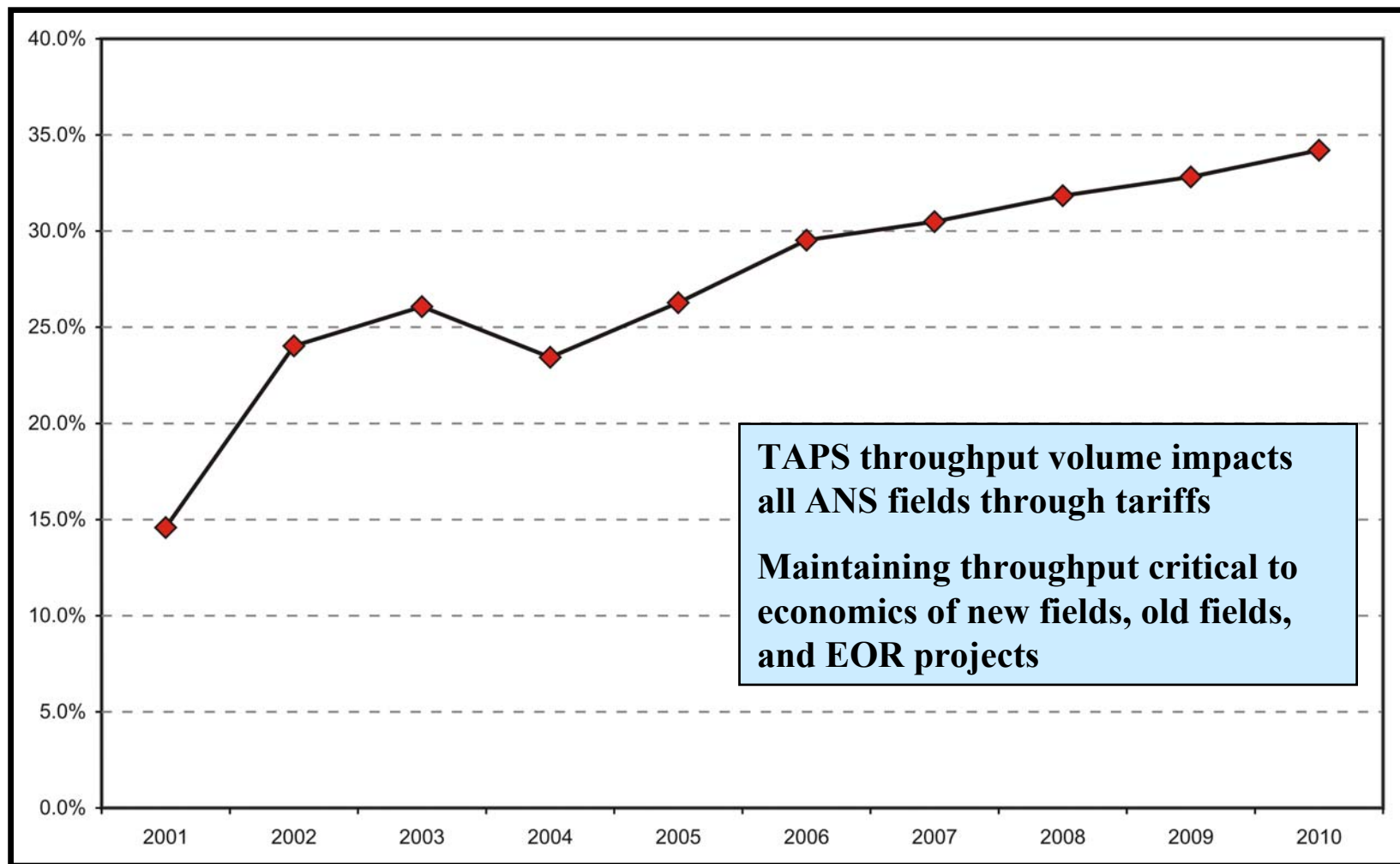
Historic and Projected Alaska Oil Production

1975 - 2022





Projected Pipeline Tariffs as a Percent of ANS Wellhead Price



Historical Perspective on EOR

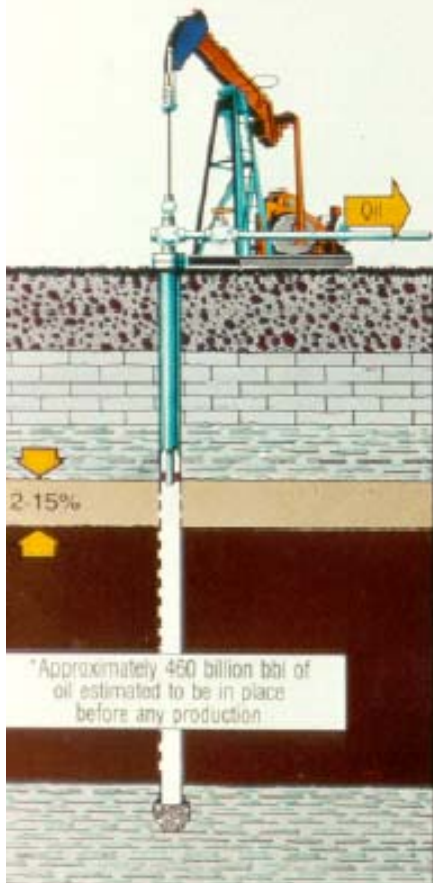
- **National Petroleum Council Definition of EOR:**
 - “... incremental oil that can be economically produced...over that which can be economically recoverable by conventional primary and secondary methods,”
- **EOR not just “tertiary recovery”**
 - Some of the best EOR projects are carried out as enhanced secondary methods or even enhanced primary
- **Current usage seems to favor the term Improved Oil Recovery (IOR)**

OIL PRODUCTION

Improved technology through research is enhancing oil recovery.

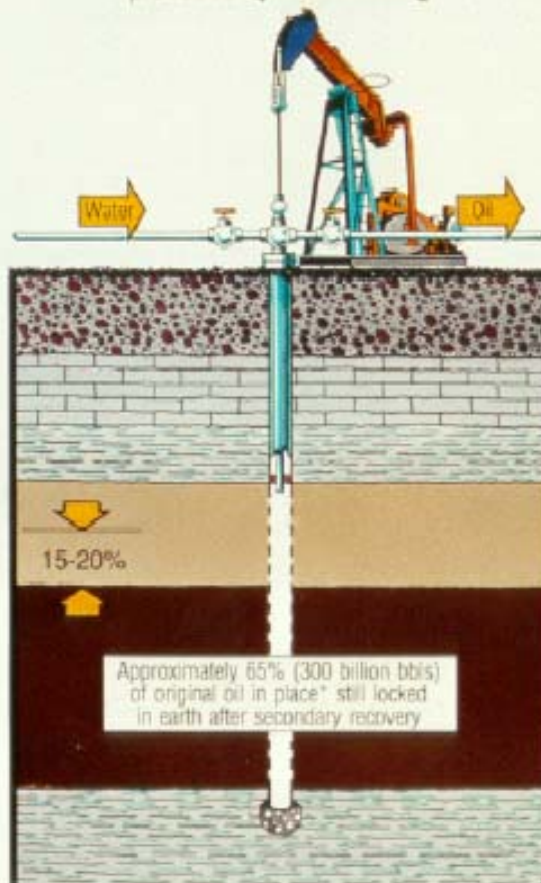
PRIMARY RECOVERY

Produces 12-15% of the original oil-in-place*



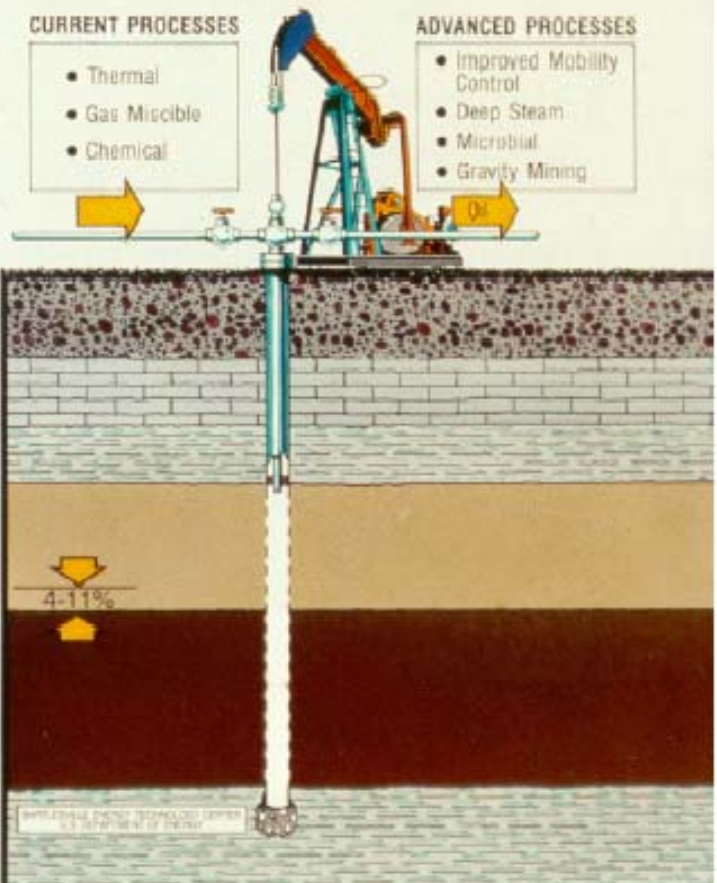
SECONDARY RECOVERY

Another 15-20% of the original oil-in-place* may be produced by waterflooding



ENHANCED OIL RECOVERY (EOR)

An additional 4-11% of the original oil-in-place* may be produced using current and advanced technology

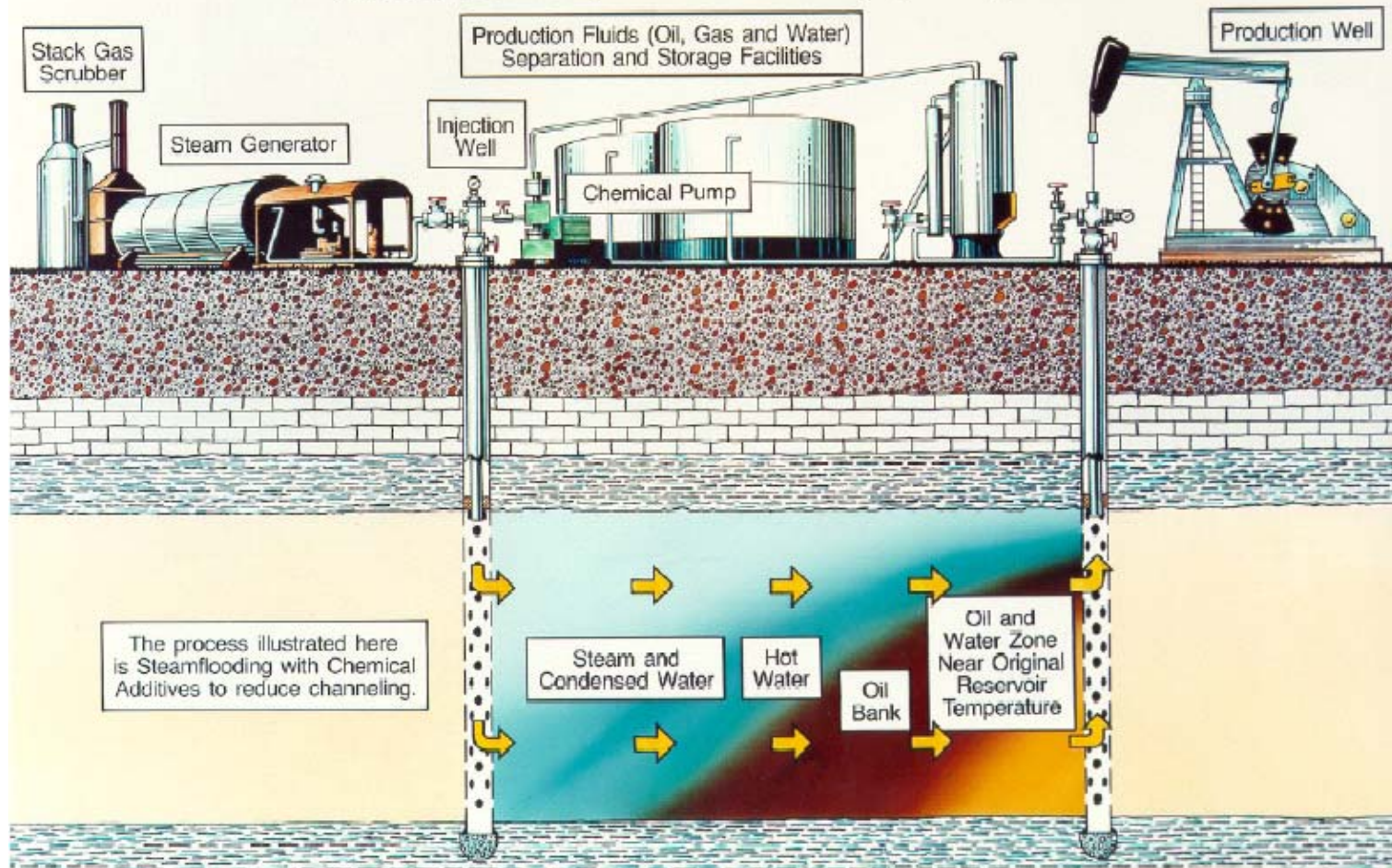


EOR Methods

- **Thermal Methods (heavy oils < 20° API)**
 - Steam assisted processes
 - In-situ combustion
- **Gas Flooding Methods**
 - CO₂, N₂, flue gas, enriched natural gas (ANS)
 - Miscible (high API gravity oils)
 - Immiscible (medium to heavy oils)
- **Chemical Methods (medium to light oils)**
 - Surfactant, polymer
- **Microbial Enhanced Oil Recovery**
 - Microorganisms offer promise of cheaper processes (acids, gases, surfactants, polymers or biomass)
- **Novel Methods**
 - Seismic/sonic stimulation
 - RF heating

THERMAL RECOVERY

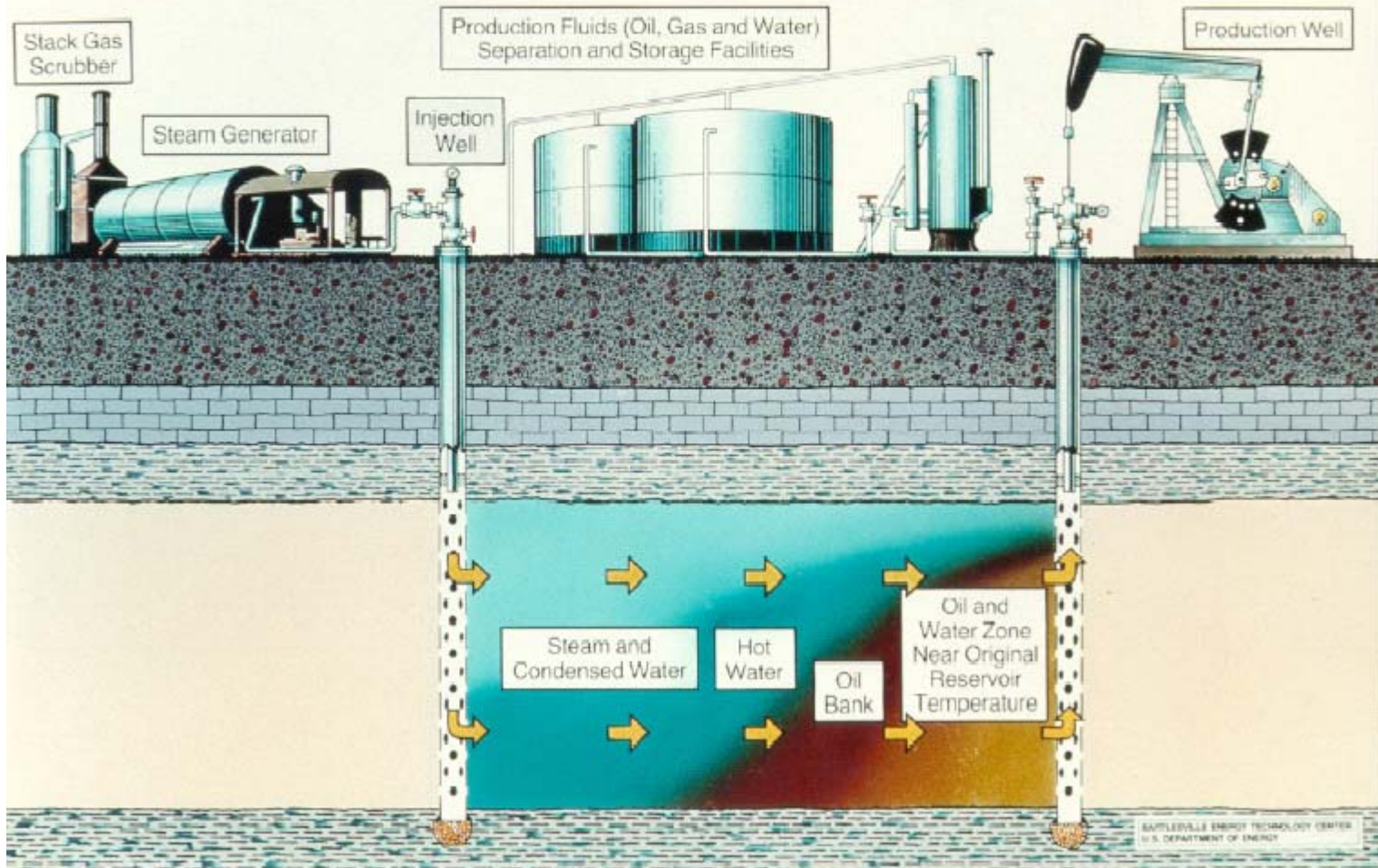
This is accomplished either by hot fluid injection (hot water or steam) or *in situ* combustion (burning a part of the crude oil in place). Variations of these methods improve production of crudes by heating them, thereby improving their mobility and ease of recovery by fluid injection.



STEAM FLOODING

Heat, from steam injected into a heavy-oil reservoir, thins the oil making it easier for the steam to push the oil through the formation toward production wells.

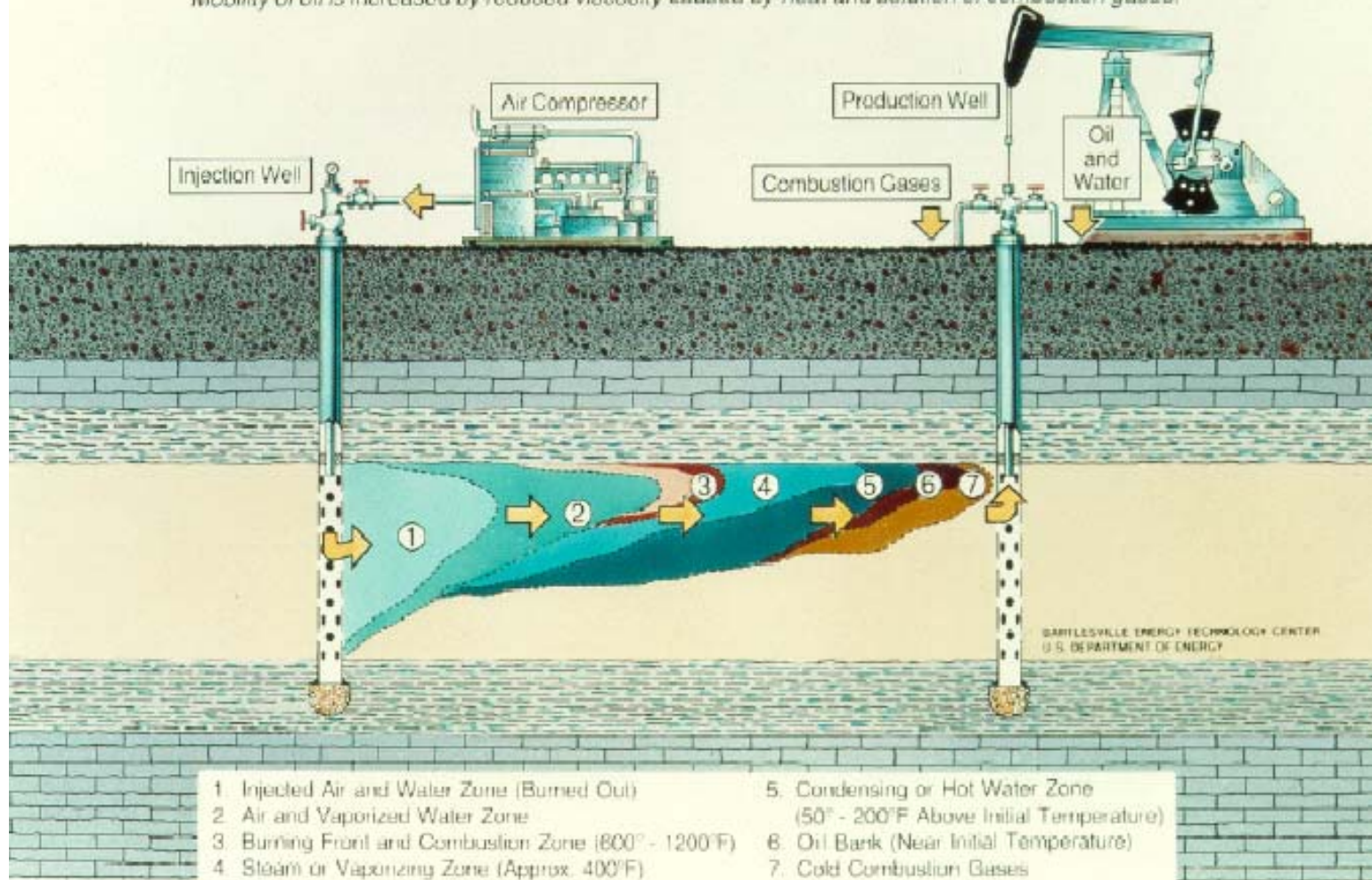
Heat reduces viscosity of oil and increases its mobility.



IN-SITU COMBUSTION

Heat is used to thin the oil and permit it to flow more easily toward production wells. In a fireflood, the formation is ignited, and by continued injection of air, a fire front is advanced through the reservoir.

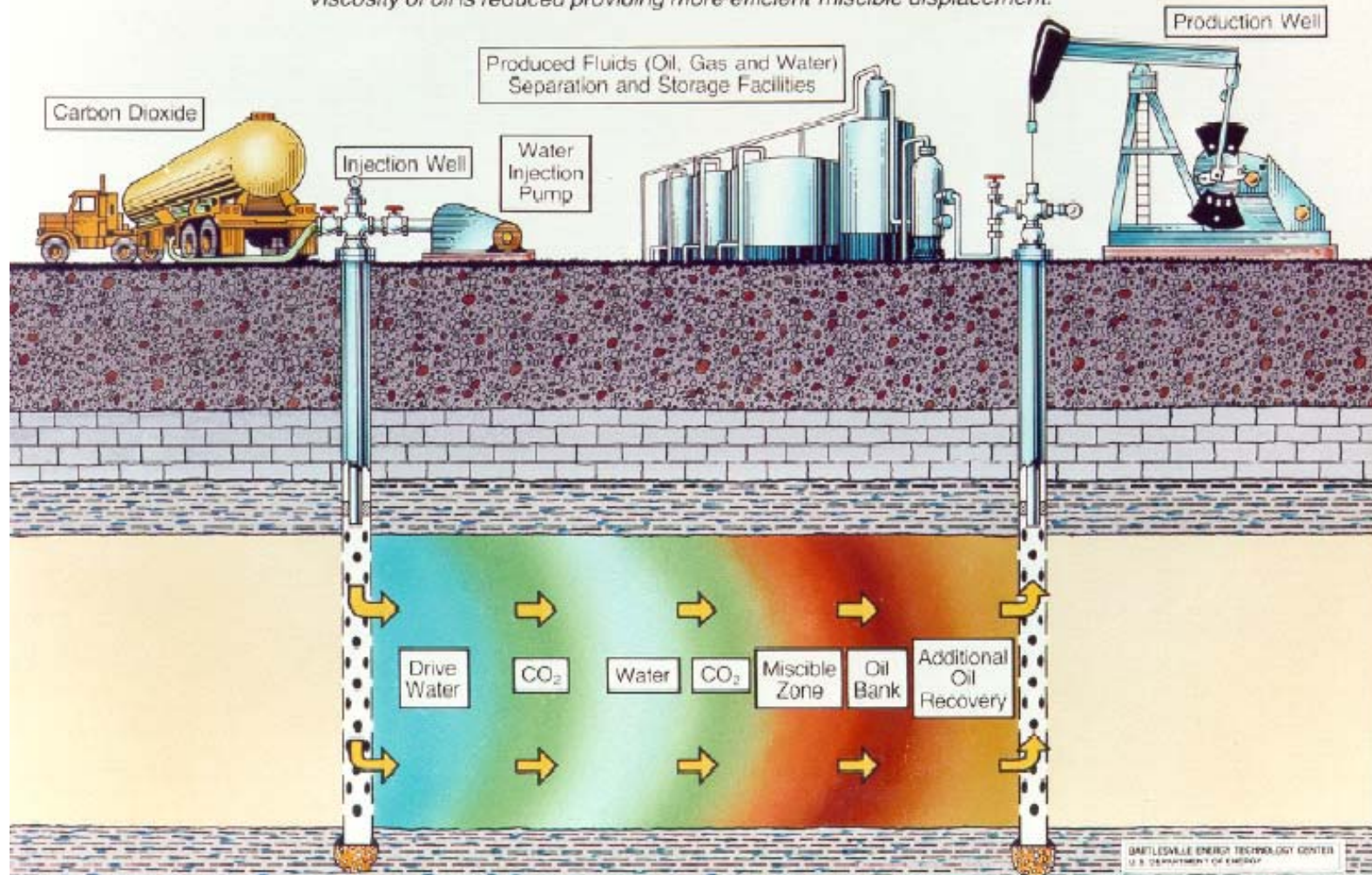
Mobility of oil is increased by reduced viscosity caused by heat and solution of combustion gases.



CARBON DIOXIDE FLOODING

This method is a miscible displacement process applicable to many reservoirs. A CO₂ slug followed by alternate water and CO₂ injections (WAG) is usually the most feasible method.

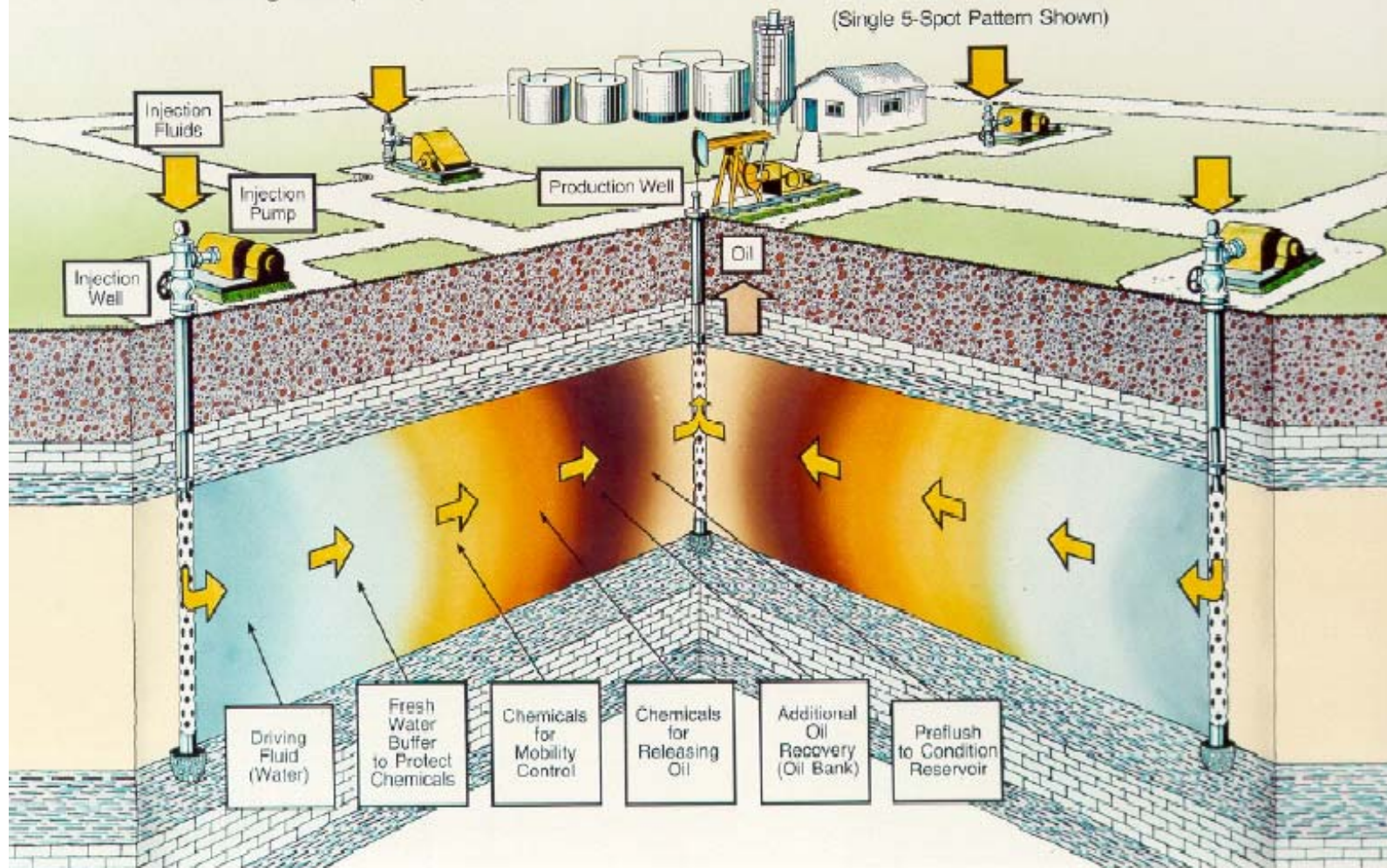
Viscosity of oil is reduced providing more efficient miscible displacement.



CHEMICAL RECOVERY

Recovery methods in this category may include surfactant, polymer and alkaline flooding. After a reservoir is conditioned by a water preflush, specific chemicals are injected to reduce interfacial tension (help release oil), and/or improve mobility control (reduce channeling). This action is followed by injecting a driving fluid (water) to move the chemicals and resulting oil bank to production wells.

(Single 5-Spot Pattern Shown)



Lessons Learned

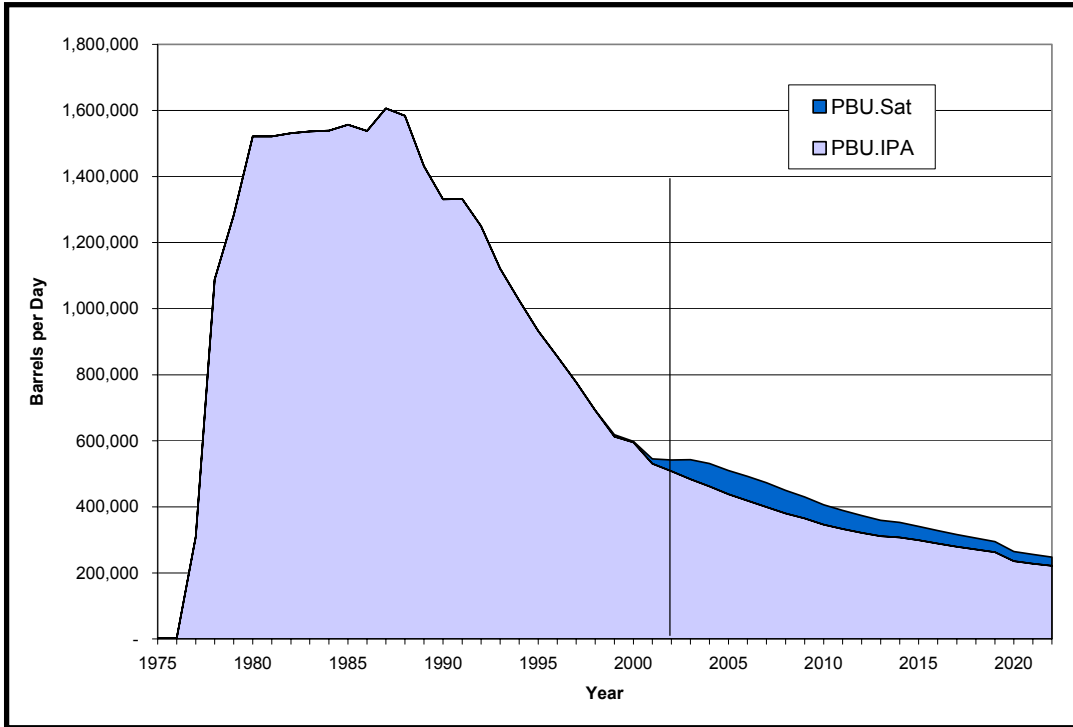
- **Early EOR field tests taught us many lessons:**
 - Recovery efficiencies much lower in the field than in the laboratory
 - Must understand the geology of target reservoirs
 - Contacting residual oil is critical \Rightarrow Methods for sweep improvement critical to success
 - Small slugs of high-cost chemicals did not work
 - Thermal and gas flooding have been most successful EOR processes
- **Must tailor EOR processes to reservoir characteristics and location-specific needs**

EOR Process Selection

- **Questions to ask?**
 - Reservoir conditions
 - Heavy oil vs. light oil
 - Shallow unconsolidated vs. deep & hot
 - Old waterflood vs. primary recovery
 - Highly fractured, layered, or homogenous sand
 - Surface environment
 - Permafrost or dry lands (ANS or West Texas)
 - Pristine area or highly developed oil province
 - Infrastructure
 - Existing or must be built
 - Environmental issues
 - Source of water, disposal of water and chemicals, subsidence, leaks
- **Product Value and Costs dictate decisions for EOR projects**



Alaska North Slope Example



Projected Ultimate Recovery

- 1980 - IPA ~9 billion barrels
- 1986 - IPA -10.2 billion barrels
- January 2000 - IPA ~ 13 billion barrels
- IPA + SAT >14 billion barrels

What brought about the increased recovery?

- Technology development
- Intelligent implementation of technology including EOR

ANS Example

- **Prudhoe Bay Unit**
 - Gas and water reinjection started at beginning of production
 - WAG process using miscible injectant started early in field life
 - Took advantage of synergistic effects of gas cap and oil rim mechanisms
 - Employed all applicable new technology as it was developed
- **Other fields – using existing infrastructure and technology to maximum extent possible**

What Next?

- **Heavy oil is a major target – 25 to 30 billion barrels OOIP in West Sak and Ugnu**
 - 3 to 6 billion barrels in reasonable target
- **Exploit existing infrastructure**
- **Develop/adapt EOR technologies appropriate to ANS infrastructure and unique environment**
 - Steam-assisted processes unlikely to be best choice
 - Expand use of MI
 - Employ CO₂ as appropriate (impact of CO₂ sequestration drivers on decision making)
- **Exploit advances in horizontal drilling, completion, and stimulations and develop new arctic-specific technology as required**
- **Develop technology for mitigation of environment issues**

Conclusions

- **Unique problems associated with ANS oil and gas production are mostly location specific**
 - Basic EOR technologies are known
 - Unique environment from surface through permafrost \Rightarrow arctic engineering is critical
 - Fragile environment requires special attention
 - Existing infrastructure must be used to maximum extent possible
 - Adapt EOR technologies for heavy oil reservoirs from other heavy oil provinces (Canada and Venezuela)

Conclusions

- **Task before us at the Workshop:**
 - Identify the technical, economic, environmental hurdles to continued development in Alaska
- **Develop the partnerships needed to remove the hurdles**
- **Work together to maintain funding levels sufficient to fund the R&D and develop the expertise to apply it effectively**

Contact Information

- **Brent Sheets, Arctic Energy Office (DOE)**
 - Office: 907-452-2559
 - E-mail: Brent.Sheets@netl.doe.gov
- **Dennis Witmer, University of Alaska Fairbanks**
 - Office Phone: 907-474-7082
 - E-mail: ffdew@uaf.edu
- **Charles Thomas, Arctic Energy Office (SAIC)**
 - Office: 907-271-1550
 - E-mail: Charles.Thomas@saic.com

